

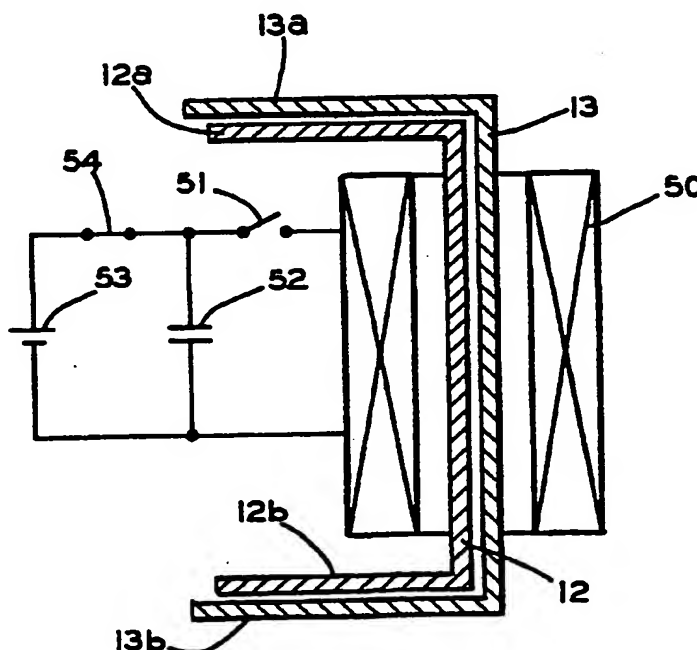
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## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : <b>H05B 6/10, B23K 13/01</b>		<b>A1</b>	(11) International Publication Number: <b>WO 97/00595</b>
			(43) International Publication Date: 3 January 1997 (03.01.97)
(21) International Application Number: PCT/US96/10371			(81) Designated States: AL, AM, AT, AU, AZ, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).
(22) International Filing Date: 14 June 1996 (14.06.96)			
(30) Priority Data: 08/491,246 16 June 1995 (16.06.95) US			
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**(54) Title: PREPARATION OF VEHICLE FRAME COMPONENTS FOR MOLECULAR BONDING USING MAGNETIC IMPULSE WELDING TECHNIQUES****(57) Abstract**

A method and apparatus for joining metallic vehicle frame components using magnetic impulse welding techniques is disclosed. In a first embodiment, an overlap joint is formed by the joinder of two individual open channel side rail sections (12, 13) to form a portion of a vehicle frame side rail. The first section (12) formed slightly smaller than the second section (13) is disposed telescopically therein with clearance. The adjacent surfaces of the sections (12, 13) are plasma or flame sprayed with a neutral interface metal. An electromagnetic coil (50) generates a magnetic field which causes the sections (12, 13) to move toward one another at a high velocity. The high velocity impact and the large pressures cause the two sections (12, 13) to weld. In a second embodiment, a pair of closed channel structural members are formed using hydroforming techniques. The end portions of the hydroformed members are then disposed concentrically within an electromagnetic coil which causes the end portions to move toward one another so as to weld.



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TITLE

PREPARATION OF VEHICLE FRAME  
COMPONENTS FOR MOLECULAR BONDING  
5 USING MAGNETIC IMPULSE WELDING TECHNIQUES

BACKGROUND OF THE INVENTION

This invention relates in general to the manufacture and assembly of vehicle frame components and in particular to a method and apparatus for  
10 preparing two or more metallic vehicle frame components for permanently joiner using magnetic impulse welding techniques.

Virtually all land vehicles in common use, such as automobiles and trucks, include a frame which serves as a platform upon which the remainder of the vehicle is built. Many vehicle frame structures are known in the art. Most of  
15 these known vehicle frame structures are formed from a number of individual metallic components which are permanently joined together. For example, a typical vehicle frame is composed of a pair of longitudinally extending side rails which are joined together by a plurality of transversely extending cross members. In shorter length vehicles, the side rails can be formed from a single  
20 piece of metal. In longer vehicles, however, each of the side rails is usually formed from two or more side rail sections which are permanently joined together. In either event, the side rails and cross members, once joined together, form a frame for supporting the remaining portions of the vehicle thereon. To facilitate the attachment of the other portions of the vehicle to the vehicle frame,  
25 a variety of brackets, hangers, cradles, and the like are often joined to the side rails and cross members at desired locations. It is common practice to also form these supporting hardware components from metallic materials, and further to permanently join them to the side rails and cross members at desired locations.

## 2

Conventional welding techniques have been commonly used to permanently join the various components of the vehicle frame together. As is well known, conventional welding techniques involve the application of heat to localized areas of two metallic members, which results in a coalescence of the two metallic members. Such welding may or may not be performed with the application of pressure, and may or may not include the use of a filler metal. Although conventional welding techniques have functioned satisfactorily in the past, there are some drawbacks to the use thereof in joining metallic vehicle frame components together. First, as noted above, conventional welding techniques involve the application of heat to localized areas of the two metallic frame members. This application of heat can cause undesirable distortions and weaknesses to be introduced into the metallic components. Second, while conventional welding techniques are well suited for joining components which are formed from similar metallic materials, it has been found to be somewhat more difficult to adapt them for use in joining components formed from dissimilar metallic materials. Third, conventional welding techniques are not easily adapted for joining components which have different gauge thicknesses. Inasmuch as the production of vehicle frames is usually an high volume, low margin process, it would be desirable to provide an improved method and apparatus for permanently joining two or more metallic vehicle frame components which avoids the drawbacks of conventional welding techniques.

### SUMMARY OF THE INVENTION

This invention relates to a method and apparatus for preparing two or more metallic vehicle frame components for permanently joinder using magnetic impulse welding techniques. In a first embodiment, the vehicle frame may include a pair of open channel side rails which are joined together by a plurality of transversely extending cross members. A plurality of brackets are joined to the side rails to facilitate the attachment of other portions of the vehicle to the vehicle frame. An overlap joint is formed by the joinder of two individual side rail sections to form a portion of a side rail. The first side rail section is initially formed slightly smaller in size than the second side rail section so that it may be disposed telescopically therein with clearance. The adjacent surfaces of the two side rail sections which are to be joined are treated by the application of a neutral interface metal, such as zinc or aluminum. The neutral interface material can be applied by means of a plasma or flame spray unit. An electromagnetic coil is provided for generating a magnetic field which causes the side rail sections to move toward one another. Portions of the electromagnetic coil are disposed on either side of the side rail sections. A first end of the electromagnetic coil is connected through a switch to a first side of a capacitor, while a second end of the electromagnetic coil is connected directly to a second side of the capacitor. A source of electrical energy is provided for selectively charging the capacitor to store a quantity of electrical energy therein. By closing the switch, electrical energy is passed from the capacitor through the electromagnetic coil. As a result, an intense electromagnetic field is generated about the first and second side rail sections. The presence of this electromagnetic field induces electrical currents in the first and second side rail sections. These electrical currents, in turn, create opposing magnetic fields which draw the first and second side rail sections into contact with one another. When this occurs, large pressures exerted on the first and second side rail sections can move them toward one another at

great velocities. The high velocity impact and the large pressures cause the two side rail sections to weld or molecularly bond. A bracket can be joined to a side rail section in a similar manner.

In a second embodiment of the invention, the vehicle frame may include a pair of closed channel structural members which are joined together. The structural members can include straight members, curved members, joint nodes, and member nodes. Some or all of these components can be formed by a hydroforming process, wherein high pressure fluid is introduced within a closed blank to expand portions thereof outwardly into conformance with an enclosing die. Initially, a closed tubular blank having a uniform circular cross sectional shape and formed from a metallic material is provided. The tubular blank may, if necessary, be pre-bent into a preform shape using a conventional tube bending apparatus. Next, the pre-bent blank is disposed within a hydroforming die, and highly pressurized fluid is introduced therein. The highly pressurized fluid causes portions of the pre-bent blank to expand outwardly into conformance with the hydroforming die. The final step is to join the formed structural members together to form the vehicle frame assembly. An electromagnetic coil can be used to cause the telescoping end portions of two structural members to move toward one another to generate a weld or molecularly bond. The adjacent concentric surfaces of the two structural components which are to be joined are treated by the application of a neutral interface metal as described above.

Various objects and advantages of this invention will become apparent to those skilled in the art from the following detailed description of the preferred embodiments, when read in light of the accompanying drawings.

### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic perspective view of a first embodiment of a vehicle frame manufactured in accordance with the method and apparatus of this invention.

5 Fig. 2 is a side elevational view of one of the side rails of the vehicle frame illustrated in Fig. 1, together with a number of brackets joined therewith, the side rail being formed from a plurality of individual side rail sections joined at overlap joints.

Fig. 3 is an enlarged perspective view of one of the overlap joints between  
10 two of the individual side rail sections illustrated in Fig. 2.

Fig. 4 is an enlarged perspective view of the two individual side rail sections illustrated in Fig. 3 prior to being joined, together with a portion of an apparatus for applying a neutral interface metal to the surfaces thereof.

Fig. 5 is a sectional elevational view of the two individual side rail  
15 sections illustrated in Fig. 4 prior to being joined together.

Fig. 6 is a sectional elevational view similar to Fig. 5 of the two individual side rail sections illustrated in Fig. 4 after being joined together.

Fig. 7 is an enlarged perspective view of a portion of one of the side rails illustrated in Fig. 1 having a bracket joined thereto.

20 Fig. 8 is an enlarged perspective view of the side rail and bracket illustrated in Fig. 7 prior to being joined, together with a portion of an apparatus for applying a neutral interface metal to the surfaces thereof.

Fig. 9 is a sectional elevational view of the side rail and bracket illustrated in Fig. 8 prior to being joined together.

25 Fig. 10 is a sectional elevational view similar to Fig. 9 of the side rail and bracket illustrated in Fig. 8 after being joined together.

Fig. 11 is a perspective view similar to Fig. 7 of an alternative structure for securing the side rail and bracket together.

Fig. 12 is a schematic perspective view of a second embodiment of a vehicle frame manufactured in accordance with the method and apparatus of this invention, including a plurality of structural members which are joined together at joints by a plurality of joint nodes.

5 Fig. 13 is an exploded perspective view of a portion of the vehicle frame illustrated in Fig. 12.

Fig. 14 is a perspective view of one of the straight members illustrated in Figs. 12 and 13.

10 Fig. 15 is a perspective view of one of the curved members illustrated in Figs. 12 and 13.

Fig. 16 is a perspective view of one of the joint nodes illustrated in Figs. 12 and 13.

Fig. 17 is a perspective view of one of the member nodes illustrated in Figs. 12 and 13.

15 Fig. 18 is a flowchart which illustrates the steps in a hydroforming process for forming the structural components illustrated in Figs. 14, 15, 16, and 17.

20 Fig. 19 is a sectional elevational view of one of the joints between a straight member and a joint node illustrated in Figs. 12 and 13 prior to being joined together.

Fig. 20 is a sectional elevational view similar to Fig. 19 of the joint between a straight member and a joint node illustrated in Figs. 12 and 13 after being joined together.

25 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, there is illustrated in Fig. 1 a first embodiment of a vehicle frame, indicated generally at 10, which has been manufactured in accordance with the method and apparatus of this invention.



The frame 10 includes a first side rail, indicated generally at 11, which extends longitudinally throughout the length of the vehicle in which it is to be used. As shown in Figs. 1 and 2, the first side rail 11 is formed from three individual side rail sections 12, 13, and 14. The first and second side rail sections 12 and 13 are  
5 joined at an overlap joint, indicated generally at 15. Similarly, the second and third side rail sections 13 and 14 are joined at an overlap joint, indicated generally at 16. The structures of the individual side rail sections 12, 13, and 14 and of the overlap joints 15 and 16 of the first side rail 11 will be described in further detail below. Although three individual rail sections 12, 13, and 14 are  
10 illustrated, it will be appreciated that the side rail 11 may be formed from any number of individual side rail sections. The frame 10 further includes a second side rail, indicated generally at 21, which also extends longitudinally throughout the length of the vehicle in which it is to be used. The second side rail 21 is formed in a similar manner as the first side rail 11, including first, second, and  
15 third individual side rail sections 22, 23, and 24 which are joined at overlap joints 25 and 26.

The side rails 11 and 21 are joined together by a plurality of transversely extending cross members 30, 31, 32, 33, and 34. These cross members 30 through 34 vary in size and shape and are intended to represent any type of cross  
20 member, cradle, or other structure which extends between the two side rails 11 and 21. The basic structures of cross member of this type are well known in the art. Additionally, a plurality of brackets 40, 41, 42, 43, 44, and 45 are joined to the side rails 11 and 21. These brackets 40 through 45 also vary in size and shape and are intended to represent any type of bracket, hanger, or other  
25 structure which is joined to the side rails 11 and 21. The basic structures of these brackets are also well known in the art.

The various components of the vehicle frame 10 discussed above are all formed from metallic materials. For example, steel has been found to be an

acceptable material to form these various components. However, this invention contemplates that other metallic materials may be used, such as aluminum, magnesium, and the like may be used. Also, it is contemplated that all of the various components of the vehicle frame 10 need not be formed from the same metallic material. Rather, some of such components may be formed from a first metallic material, while others may be formed from a second metallic material.

The vehicle frame 10 is formed by joining the various side rails 11 and 21, cross members 30 through 34, and brackets 40 through 45 together. Some of these components may be joined together by the use of mechanical fasteners, such as bolts, if desired. However, this invention relates to a method and apparatus for permanently joining these components together using a magnetic impulse welding techniques, which will be described below. Magnetic impulse welding techniques have been found to be preferable to conventional welding techniques in the formation of vehicle frames, as discussed above.

Referring now to Fig. 3, there is illustrated an enlarged perspective view of the overlap joint 15 between the ends of the individual side rail sections 12 and 13 illustrated in Figs. 1 and 2. As shown therein, the rearward end of the first side rail section 12 includes a vertically extending web portion having an upper horizontal flange portion 12a and a lower horizontal flange portion 12b extending therefrom. Similarly, the forward end of the second side rail section 13 includes a vertically extending web portion having an upper horizontal flange portion 13a and a lower horizontal flange portion 13b extending therefrom. Although the ends of the first and second side rail sections 12 and 13 are shown as having generally open channel or C-shaped cross sectional shapes, it will be appreciated that they may be formed having other cross sectional shapes. Also, it will be appreciated that the cross sectional shapes of the first and second side rail sections 12 and 13 need not be uniform throughout their entire lengths, nor

does the cross sectional shape of the first side rail section 12 have to be the same as the cross sectional shape of the second side rail section 13.

Fig. 4 illustrates a treatment the two side rail sections 12 and 13 prior to assembly. When the two side rail sections 12 and 13 are formed from dissimilar metallic material, it is desirable that the surfaces thereof which are to be joined be treated by the application of a neutral interface metal. Zinc and aluminum are two neutral interface materials which can be used. However, other neutral interface materials may be used, depending upon the specific metallic materials which are used to form the two side rail sections 12 and 13. The neutral interface material can be applied by means of a conventional plasma or flame spray unit, indicated schematically at 46 and 47. The purpose of the neutral interface material is to reduce or eliminate corrosion of the side rail sections 12 and 13 caused by the joinder of two dissimilar metallic materials.

Referring now to Fig. 5, it can be seen that the first side rail section 12 is initially formed slightly smaller in size than the second side rail section 13, prior to being joined together. Thus, the first side rail section 12 may initially be disposed telescopically within the second side rail section 13 with clearance, as shown in Fig. 5. When so disposed, the vertically extending web portions of the side rail sections 12 and 13 are disposed generally parallel and adjacent to one another, as are the upper horizontal flange portions 12a and 13a and the lower horizontal flange portions 12b and 13b. Although the clearance between the respective portions of the side rail sections 12 and 13 may be adjusted as desired, it has been found acceptable to provide a clearance in the range of from 0.050 inch to 0.100 inch.

An electromagnetic coil 50 is provided for generating a magnetic field which, as will be explained further below, causes the side rail sections 12 and 13 to move toward one another. Portions of the electromagnetic coil 50 are disposed on either side of the side rail sections 12 and 13. The electromagnetic

coil 50 is embodied as a plurality of windings of an electrical conductor. A first end of the electrical conductor is connected through a first switch 51 to a first side of a capacitor 52, while a second end of the electrical conductor is connected directly to a second side of the capacitor 52. The capacitor 52 is  
5 representative of a number of high voltage capacitors which are connected together in parallel. A source of electrical energy 53 is provided for selectively charging the capacitor 52 to store a quantity of electrical energy therein. A first side of the source of electrical energy 53 is connected through a second switch 54 to the first side of the capacitor 52, while a second side of the source of  
10 electrical energy 53 is connected directly to the second side of the capacitor 52.

In operation, the first switch 51 is initially opened and the second switch is initially closed, as shown in Fig. 5. In this condition, electrical energy is transferred from the source of electrical energy 53 into the capacitor 52. When a sufficient amount of electrical energy has been stored in the capacitor 52, the  
15 second switch 54 is opened and the first switch 51 is closed, as shown in Fig. 6. By closing the first switch 51, energy in the form of electrical current is discharged from the capacitor 52 through the electromagnetic coil 50. As a result, an intense electromagnetic field is generated about the first and second side rail sections. The presence of this electromagnetic field induces electrical  
20 currents in the first and second side rail sections 12 and 13. These electrical currents, in turn, create opposing magnetic fields which draw the first and second side rail sections 12 and 13 into contact with one another. When this occurs, a large pressure exerted on the first and second side rail sections 12 and 13 move them toward one another at a high velocity.

25 The high velocity impact of the first and second side rail sections 12 and 13, as well as the large pressures exerted thereon, cause the two components to weld or molecularly bond. The sizes and shapes of the side rail sections 12 and 13, the size and shape of the electromagnetic coil 50, and the strength of the

electromagnetic field are all factors which will determine where the deformation of the first and second side rail sections 12 and 13 will occur, as well as which portions thereof will be joined together.

Referring now to Fig. 7, there is illustrated an enlarged perspective view of a portion of the individual side rail section 12 and the bracket 45 illustrated in Figs. 1 and 2. As discussed above, the first side rail section 12 includes the vertically extending web portion having the upper horizontal flange portion 12a and the lower horizontal flange portion 12b extending therefrom. The bracket 45 is formed having a vertically extending web portion having an upper horizontal flange portion 45a extending therefrom. The neutral interface material can be applied by means of a conventional plasma or flame spray unit, indicated schematically at 56 and 57 in Fig. 8. The vertically extending web portions of the first side rail section 12 and the bracket 45 are then disposed in spaced apart relationship, generally parallel and adjacent to one another as shown in Fig. 9. Portions of the electromagnetic coil 50 are disposed on either side of the side rail section 12 and the bracket 45. The operation of the electromagnetic coil 50 is the same as described above, and functions to weld or molecularly bond the side rail section 12 with the bracket 45, as shown in Fig. 10.

Fig. 11 illustrates an alternative structure for securing the side rail 12 and the bracket 45 together. As shown therein, the coil 50 is disposed concentrically about an elongated cylindrical mandrel 48. The mandrel 48 is formed from a material which, when a magnetic field is generated by energization of the electromagnetic coil 50, is urged for movement in the direction indicated by the arrow. One end of the mandrel 48 is located adjacent to the vertically extending web portion of the bracket 45. The bracket 45 may be secured to the end of the mandrel 48 or may simply be disposed adjacent thereto. In either event, when the electromagnetic coil 50 is energized as described above, the mandrel 48 and the vertically extending web portion of the bracket 45 are driven axially toward

the side rail 12 at a high velocity. In this manner, the bracket 45 is welded or molecularly bonded to the side rail 12 similarly as described above.

The side rails 11 and 12 described above are all shown as being formed from open channel stock, i.e., stock which has a non-closed cross sectional shape. The specifically illustrated side rails 11 and 12 are formed having a generally open C-shaped cross section. It will be appreciated that this invention may be practiced using open channel stock having other cross sectional shapes. For example, the side rails 11 and 12 may be formed having a generally closed C-shaped cross section (wherein short flanges are provided at the ends of the illustrated side rails 11 and 12 which extend inwardly toward one another), a generally hat-shaped cross section (wherein short flanges are provided at the ends of the illustrated side rails 11 and 12 which extend outwardly apart from one another), or other open channel configurations.

Referring now to Figs. 12 and 13, there is illustrated a second embodiment of a vehicle frame assembly, indicated generally at 60, in accordance with this invention. The illustrated vehicle frame assembly 60 is an automobile space frame, i.e., a frame for an automobile which defines an enclosed space for occupants. However, as is apparent from the preceding discussion, this invention may be utilized in a flat bed frame or any other frame structure for any type of vehicle. The illustrated vehicle frame assembly 60 is composed of four different types of structural components which are secured together. The first type of structural component is referred to as a straight member, such as shown at 61. Straight members 61 are characterized as being linear and elongated in shape. The straight members 61 are hollow and can be formed having any desired cross sectional shape. For example, as shown in Fig. 14, a straight member 61 may be formed having a central portion 61a which is square or rectangular in cross sectional shape and a pair of end portions 61b which are circular in cross sectional shape. The square or rectangular cross

sectional shape of the central portion 61a of the straight member 61 is desirable because it provides stiffness to the straight member 61 and facilitates the attachment of other components thereto, such as brackets and the like. As will be explained in greater detail below, the circular cross sectional shape of the end portions 61b of the straight member 61 is desirable because it facilitates the attachment of other structural components of the vehicle frame assembly 60.

The second type of structural component in the vehicle frame assembly 60 is referred to as a curved member, such as shown at 62. Curved members 62 are similar to straight members 61 in that they are hollow and elongated. However, curved members 62 are not linear in shape like the straight members 61, but rather extend non-linearly. For example, as shown in Fig. 15, a curved member 62 may be formed having a single bend portion 62a which is located between two linear portions 62b. Alternatively, the curved member 62 may be formed having a plurality of bend portions 62a separating adjacent linear portions 62b, or it may be curved along its entire length. Preferably, for the same reasons as stated above with respect to the straight member 61, the linear portions 62b near the center of the curved member 62 are square or rectangular in cross sectional shape. Two end portions 62c are provided on the curved member 62 which are circular in cross sectional shape, also for the same reasons as stated above.

The third type of structural component in the vehicle frame assembly 60 is referred to as a joint node, such as shown at 63. Joint nodes 63 are characterized as relatively small components which are provided to join adjacent components of the vehicle frame assembly 60 at a joint. For example, as shown in Fig. 16, a joint node 63 may be formed having a relatively small body portion 63a with a plurality (three in the illustrated embodiment) relatively short joint portions 63b extending outwardly therefrom. The joint portions 63b are typically linear because of their relatively short length, although such is not required. The body portion 63a and the joint portions 63b are hollow and can be

formed having any desired cross sectional shape. Again, for the same reasons stated above with respect to the straight member 61, the body portion 63a and adjacent areas of the joint portions 63b are preferably square or rectangular in cross sectional shape. Two end portions 63c are provided on the joint member  
5 63 which are circular in cross sectional shape, also for the same reasons as stated above.

The fourth type of structural component in the vehicle frame assembly 60 is referred to as a member node, such as shown at 64. Member nodes 64 are characterized as elongated components which are also provided to join adjacent  
10 components of the vehicle frame assembly 60 at a joint. For example, as shown in Fig. 17, a member node 64 may be formed having an elongated central portion 64a, a pair of end portions 64b, and one or more (three in the illustrated embodiment) relatively short joint portions 64c extending outwardly therefrom. As with the joint portion 63b described above, the joint portions 64c are  
15 typically linear because of their relatively short length, although such is not required. The central portion 64a, the end portions 64b, and the joint portions 64c are hollow and can be formed having any desired cross sectional shape. Again, for the same reasons stated above with respect to the straight member 61, the central portion 64a and adjacent areas of the joint portions 64c are preferably  
20 square or rectangular in cross sectional shape. End portions 62d are provided on the curved member 62 which are circular in cross sectional shape, also for the same reasons as stated above.

Each of the four types of structural components 61, 62, 63, and 64 used to form the vehicle frame assembly 60 is preferably formed by hydroforming  
25 techniques. Hydroforming is a metal deformation process which, generally speaking, utilizes high pressure fluid introduced within a closed workpiece to expand portions of the workpiece outwardly into conformance with an enclosing die. Fig. 18 is a flowchart 70 which illustrates the steps in the hydroforming



process of this invention for forming any one or all of the four types of structural components 61, 62, 63, and 64 used to form the vehicle frame assembly 60. The first step 71 in the hydroforming process is to provide a closed blank. Typically, the closed blank is a tubular blank having a uniform circular cross sectional  
5 shape and formed from a metallic material. As discussed above, it is desirable that relatively lightweight strong metallic materials, such as aluminum, magnesium, and the like, be used. However, steel and other heavier metallic materials may be used as well.

Second, it is usually, but not always, necessary to pre-bend the tubular  
10 blank into a preform shape, as shown at 72. Such pre-bending is necessary when the final desired shape of the structural component is dramatically different from the initial shape of the tubular blank. Thus, pre-bending may not be required when forming a straight member 61 because of its generally linear shape, but may be required when forming a curved member 62. Several pre-bending  
15 operations may be performed on a single blank, depending upon the final desired shape for the structural component. Following this pre-bending, the blank follows the general shape of the structural component to be formed, but still has a generally uniform circular cross sectional shape throughout its entire length. The pre-bending step may be performed on a conventional tube bending  
20 apparatus or other similar mechanism.

Next, the pre-bent blank is disposed within a hydroforming die, and highly pressurized fluid is introduced therein, as shown at 73. The highly pressurized fluid within the pre-bent blank causes portions thereof to expand outwardly into conformance with the enclosed hydroforming die. In this  
25 manner, the portions of the structural members 61, 62, 63, and 64 having the square or rectangular cross sectional shapes discussed above can be formed. At the same time, various openings (not shown) or other structures may be formed on the structural components as desired, such as for facilitating the connection of

## 16

other components (brackets, etc.) to the vehicle frame assembly 60. The hydroforming step can be performed on any conventional hydroforming apparatus.

The fourth step in the process of forming the vehicle frame assembly is to  
5 treat the surfaces of the two structural components to be joined together, as shown at 74. As discussed above, when the two structural components are formed from dissimilar metallic material, it is desirable that the surfaces thereof which are to be joined be treated by the application of a neutral interface metal. Zinc and aluminum are two neutral interface materials which can be used.  
10 However, other neutral interface materials may be used, depending upon the specific metallic materials which are used to form the two structural components. The neutral interface material can be applied by means of a conventional plasma or flame spray unit as described above for reducing or eliminating corrosion of the structural components caused by the joinder of two dissimilar metallic  
15 materials.

The final step in the process of forming the vehicle frame assembly is to join the formed structural members together, as shown at 75 in the flowchart 70. Referring now to Figs. 19 and 20, the formation of a joint between one of the straight members 61 and one of the joint nodes 63 is illustrated. The end portion  
20 61b of the straight member 61 is initially formed slightly larger in size than the end portion 63c of the joint portion 63b of the joint node 63, prior to being joined together. Thus, the end portion 63c of the joint node 63 may initially be disposed telescopically within the end portion 61b of the straight member 61 with an annular clearance, as shown in Fig. 19. When so disposed, the outer  
25 cylindrical surface of the end portion 63c of the joint node 63 is disposed generally concentric with the inner cylindrical surface of the end portion 61b of the straight member 61. Although the clearance between these cylindrical

surfaces may be adjusted as desired, it has been found acceptable to provide a clearance in the range of from 0.050 inch to 0.100 inch.

An electromagnetic coil 80 is provided for generating a magnetic field which, as will be explained further below, causes the end portion 63c of the joint node 63 and the end portion 61b of the straight member 61 to move toward one another. The electromagnetic coil 80 is disposed concentrically about the end portion 61b of the straight member 61. The electromagnetic coil 80 is similar in structure and operation to the electromagnetic coil 50 described above, and the same control circuit may be used to operate same. Thus, when the switches 51 and 54 are operated as described above, the electromagnetic field generated by the coil 80 causes the end portion 61b of the straight member 61 to move toward the end portion 63c of the joint node 63 at a high velocity. As a result, the end portion 61b of the straight member 61 and the end portion 63c of the joint node 63 are welded or molecularly bonded as described above.

As also discussed above, the various components of the vehicle frame 60 need not be formed from the same metallic material. Rather, some of such components may be formed from a first metallic material, while others may be formed from a second metallic material. For example, referring back to Fig. 10, it will be appreciated that the various structural components which are located in the upper portion of the vehicle frame assembly 60 (i.e., those structural components which extend upwardly from the bed portion of the vehicle frame assembly 60 to form the sides and roof of the passenger compartment) may be formed from a first relatively lightweight material, such as magnesium. The various structural components which are located in the lower portion of the vehicle frame assembly 60 (i.e., those structural components which form the bed portion of the vehicle frame assembly 60) may be formed from a second relatively heavier material, such as aluminum. Additionally, or alternatively, steel may be used in portions of the vehicle frame assembly 60 in conjunction

with either or both of the magnesium and aluminum materials. The above-described process for molecular bonding of vehicle frame components using magnetic impulse welding techniques is advantageous because the adjacent dissimilar metals have been found not to cause corrosion when joined in this  
5 manner.

In accordance with the provisions of the patent statutes, the principle and mode of operation of this invention have been explained and illustrated in its preferred embodiment. However, it must be understood that this invention may be practiced otherwise than as specifically explained and illustrated without  
10 departing from its spirit or scope.

What is claimed is:

1. An apparatus for permanently joining two metallic vehicle frame components comprising:

- means for supporting portions of the first and second metallic vehicle  
5 frame components adjacent to one another;  
means for applying a neutral interface metal to adjacent surfaces of the  
first and second metallic vehicle components;  
an electromagnetic coil;  
a source of electrical energy; and  
10 means for selectively connecting said electromagnetic coil to said source  
of electrical energy so as to generate an electromagnetic field adapted to cause  
the first and second metallic vehicle frame components to move into contact with  
one another at a high velocity so as to cause the first and second metallic vehicle  
frame components to be permanently joined together.

15

2. The apparatus defined in Claim 1 wherein a portion of said  
electromagnetic coil is adapted to extend concentrically about the portions of the  
first and second metallic vehicle frame components.

20

3. The apparatus defined in Claim 2 wherein said electromagnetic  
coil is annular in shape.

25

4. The apparatus defined in Claim 1 wherein said means for  
supporting portions of the first and second metallic vehicle frame components  
includes a mandrel adapted to engage the first metallic vehicle frame component,  
said electromagnetic field causing movement of said mandrel to move the first  
metallic vehicle frame component into contact with the second metallic frame

component at a high velocity so as to cause the first and second metallic vehicle frame components to be permanently joined together.

5        5.        The apparatus defined in Claim 1 wherein said means for applying a neutral interface metal is performed by plasma spraying.

6.        The apparatus defined in Claim 1 wherein said means for applying a neutral interface metal is performed by flame spraying.

10        7.        A method for permanently joining two metallic vehicle frame components comprising the steps of:

- (a)        supporting portions of the first and second metallic vehicle frame components adjacent to one another;
- (b)        applying a neutral interface metal to adjacent surfaces of the first
- 15        and second metallic vehicle components;
- (c)        providing an electromagnetic coil;
- (d)        selectively connecting the electromagnetic coil to a source of electrical energy so as to generate an electromagnetic field, thereby causing the first and second metallic vehicle frame components to move into contact with
- 20        one another at a high velocity so as to be permanently joined together.

8.        The method defined in Claim 7 wherein the electromagnetic coil is provided concentrically about the portions of the first and second metallic vehicle frame components.

25

9.        The method defined in Claim 7 wherein said step (a) includes the steps of providing a mandrel adapted to engage the first metallic vehicle frame component and generating the electromagnetic field so as to cause movement of

the mandrel to move the first metallic vehicle frame component into contact with the second metallic frame component at a high velocity so as to cause the first and second metallic vehicle frame components to be permanently joined together.

5

10. The method defined in Claim 7 wherein said step (b) is performed by plasma spraying.

11. The method defined in Claim 7 wherein said step (b) is performed  
10 by flame spraying.

12. A method of manufacturing a portion of a vehicle frame assembly comprising the steps of:

(a) providing a first structural component having a closed cross  
15 sectional shape and a second structural component;

(b) forming the first structural component to a desired shape by hydroforming; and

(c) applying a neutral interface metal to adjacent surfaces of the first and second metallic vehicle components;

20 (d) permanently joining the first and second structural components by magnetic impulse welding.

13. The method defined in Claim 12 wherein said step (a) includes the step of providing the second structural component having a closed cross  
25 sectional shape.

14. The method defined in Claim 13 wherein said step (b) includes the step of forming the second structural component to a desired shape by hydroforming.

5 15. The method defined in Claim 12 further including the step of pre-bending one of the first and second structural components prior to said step (b).

16. The method defined in Claim 7 wherein said step (b) is performed by plasma spraying.

10

17. The method defined in Claim 7 wherein said step (b) is performed by flame spraying.



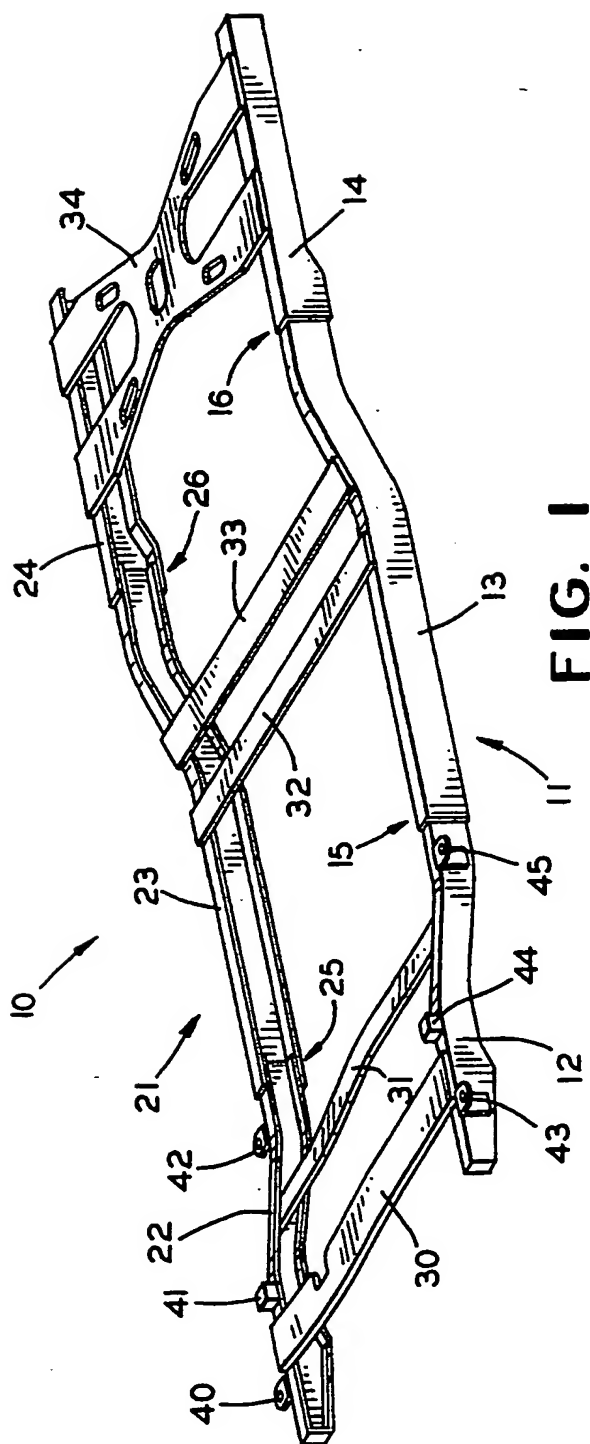


FIG. 1

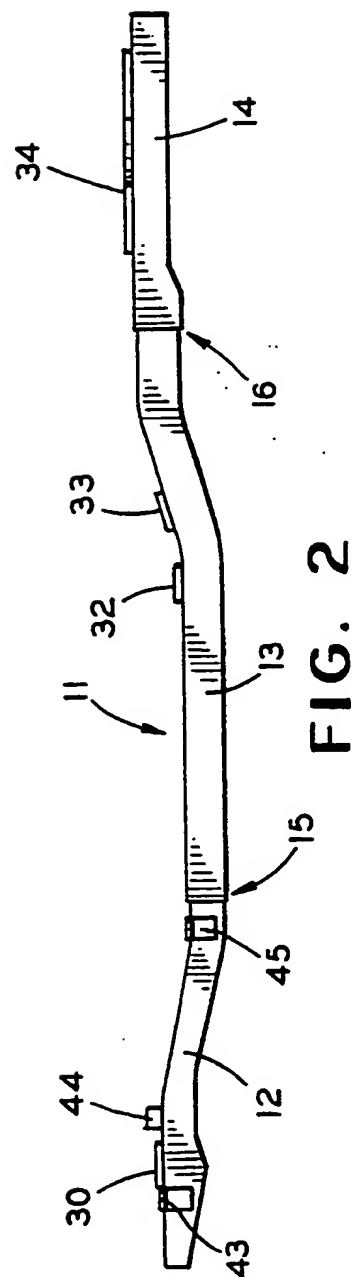
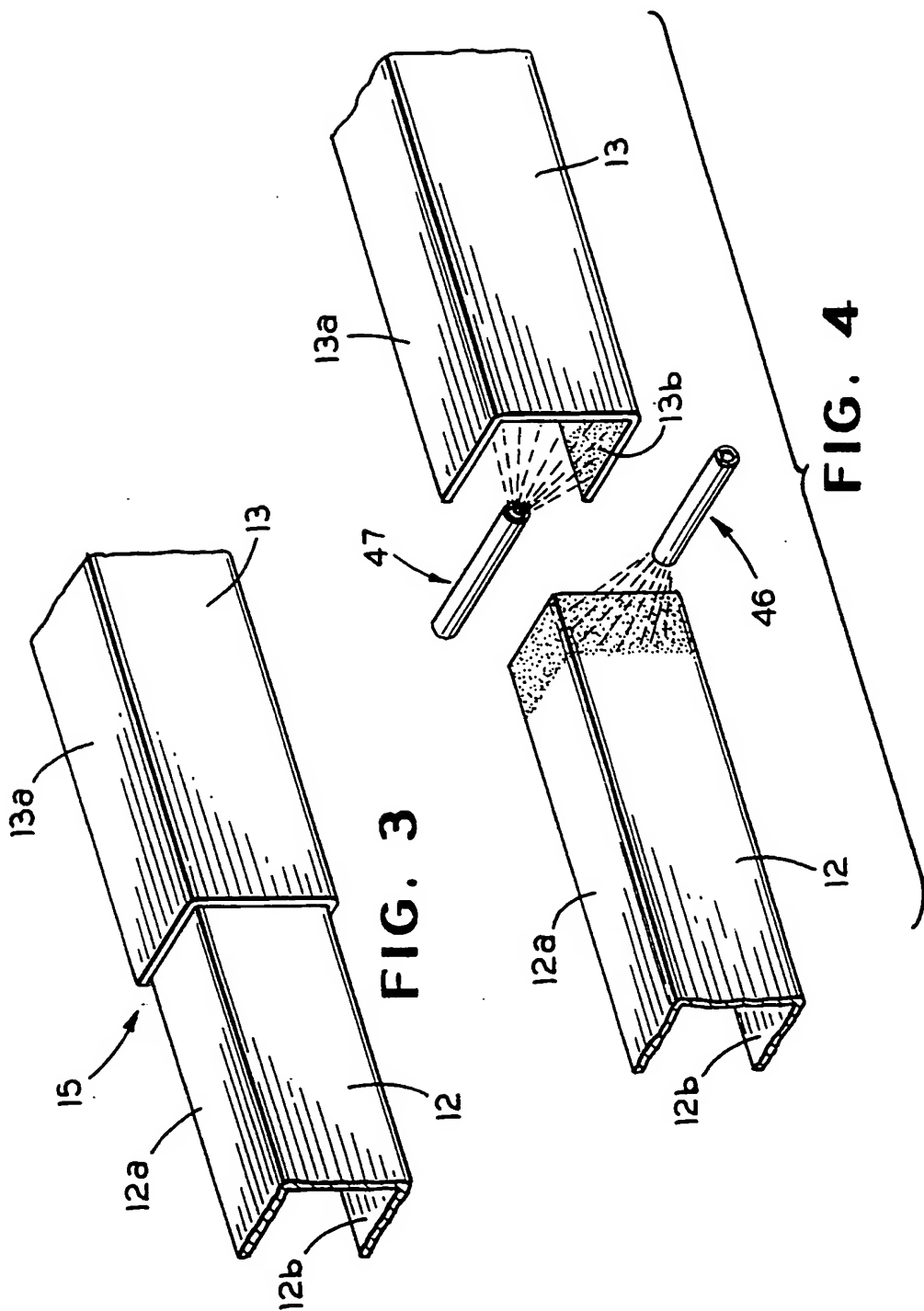
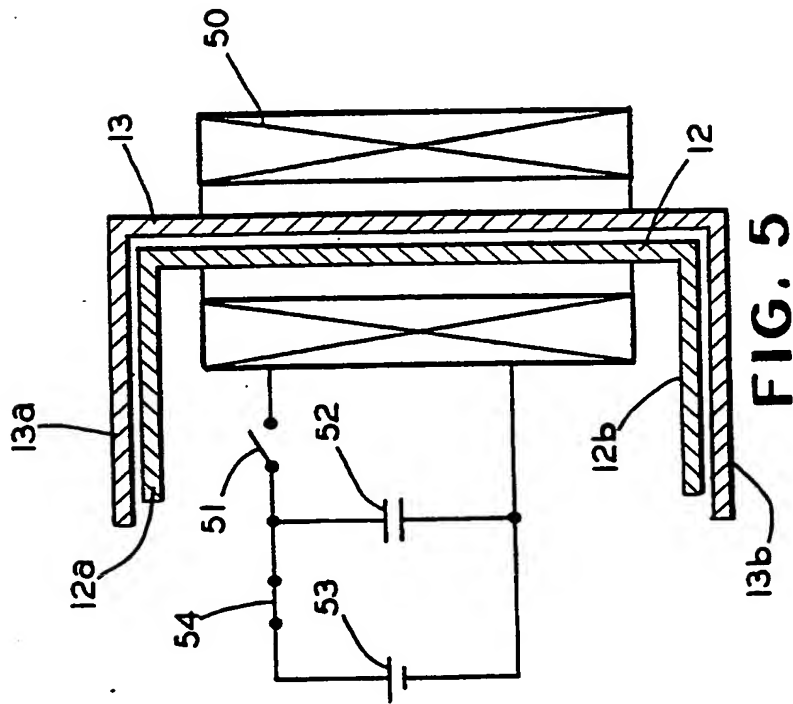
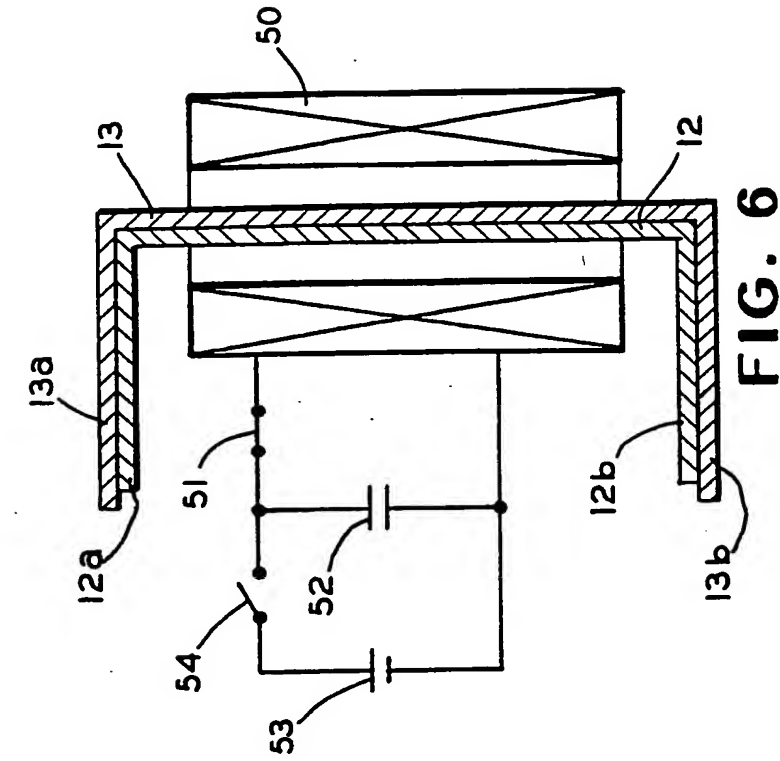
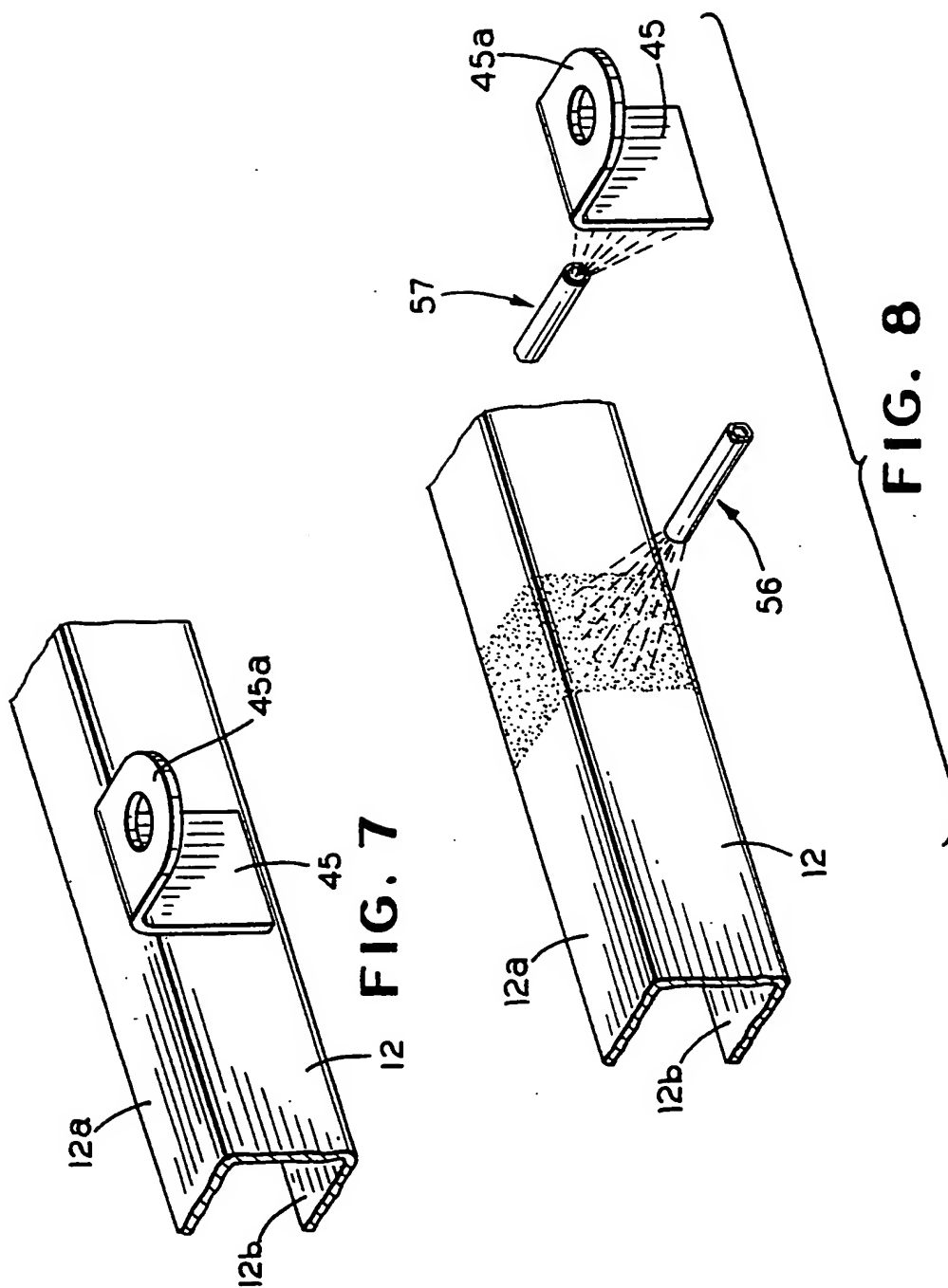


FIG. 2







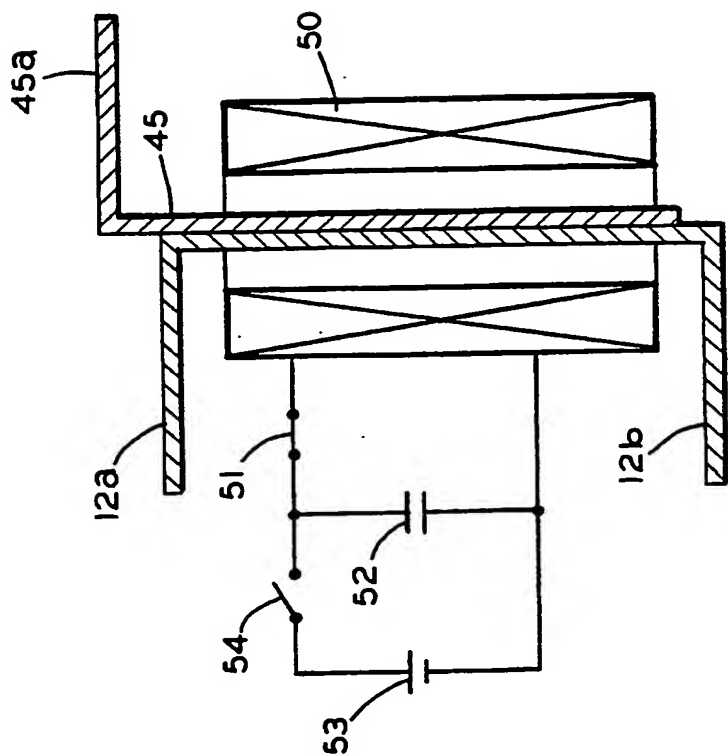


FIG. 10

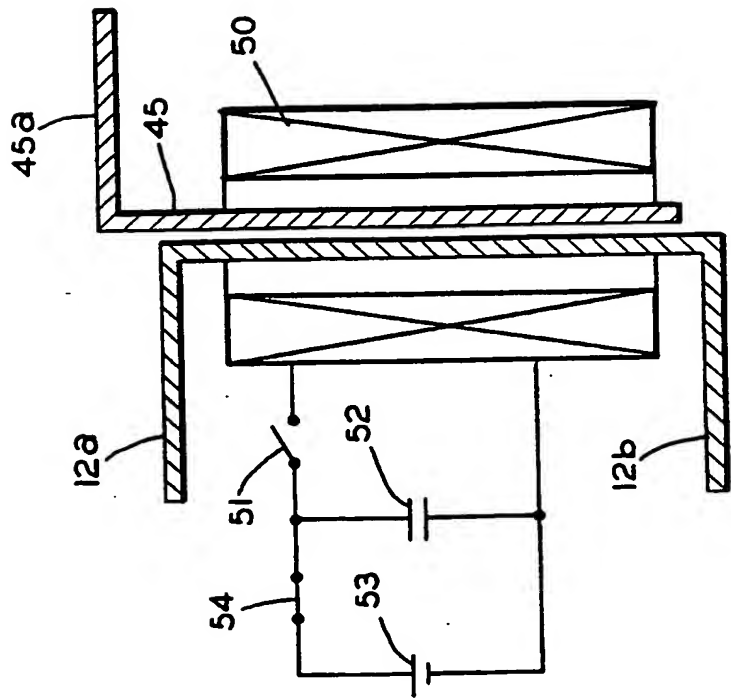
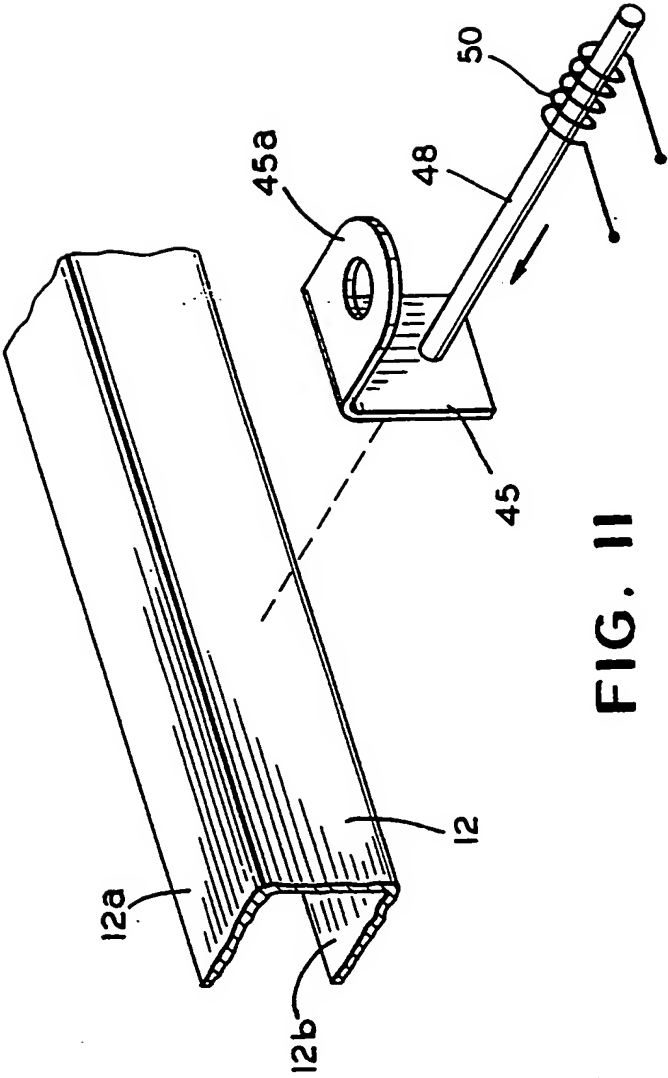


FIG. 9



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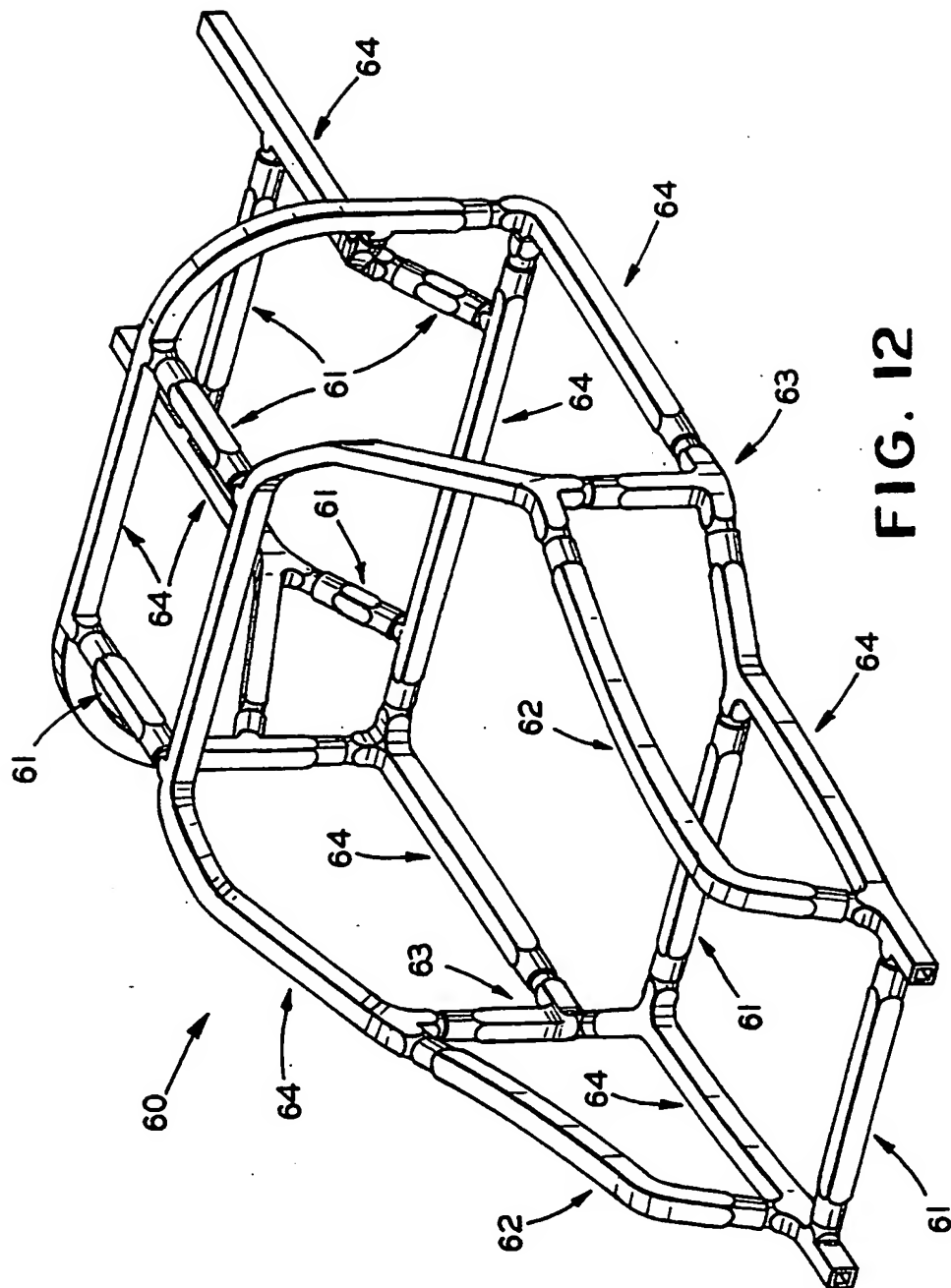


FIG. 12

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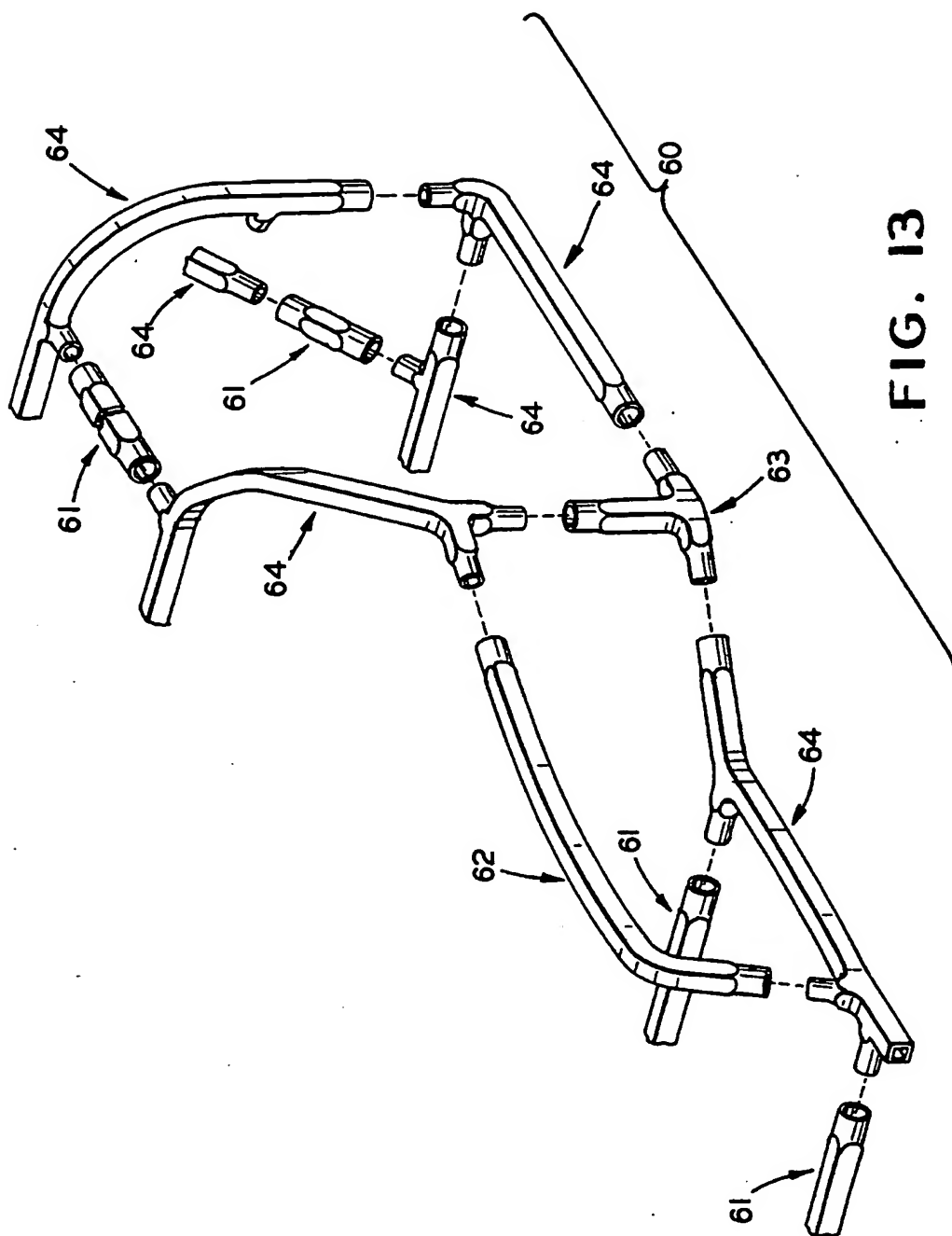
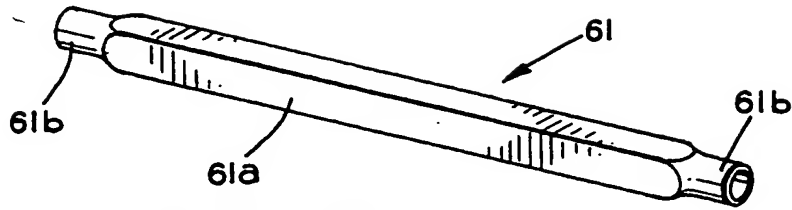


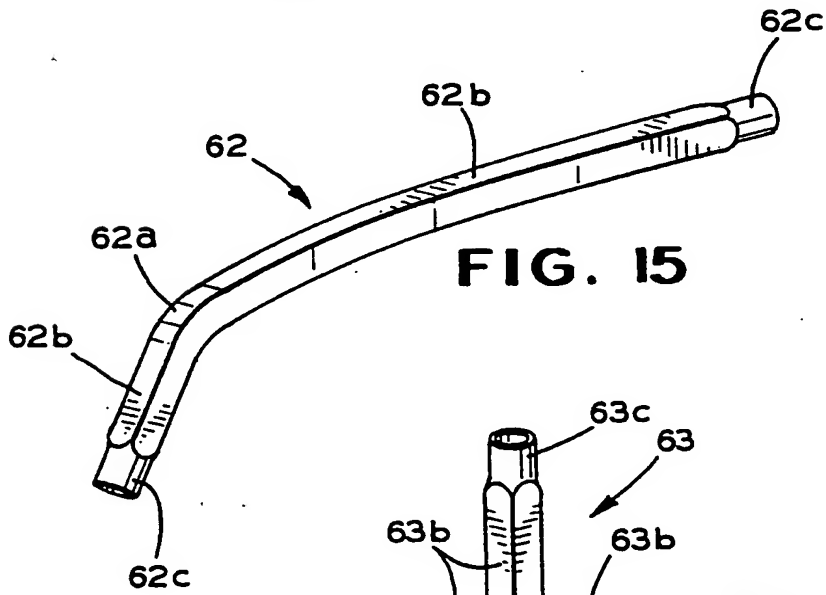
FIG. 13



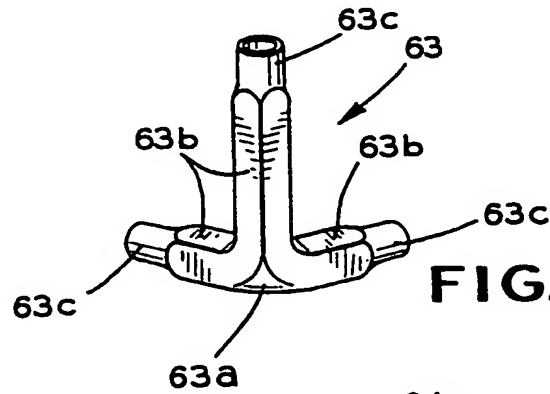
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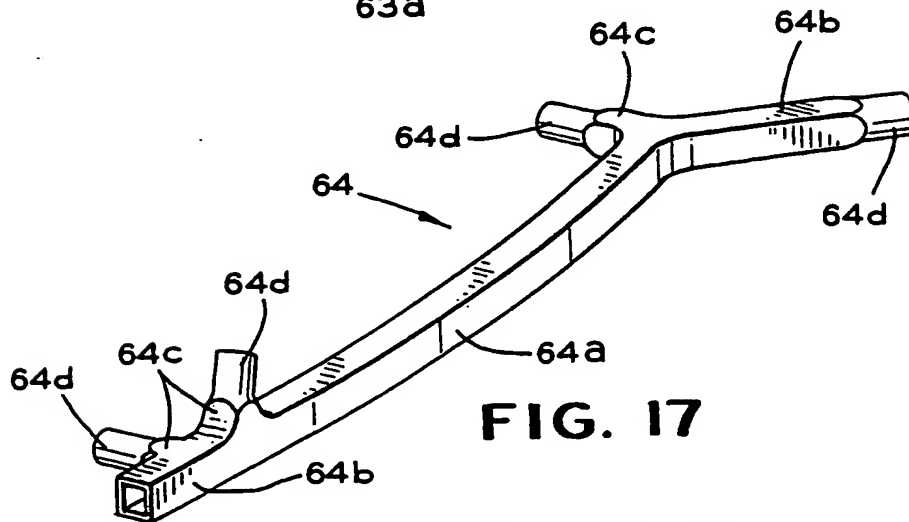
**FIG. 14**



**FIG. 15**



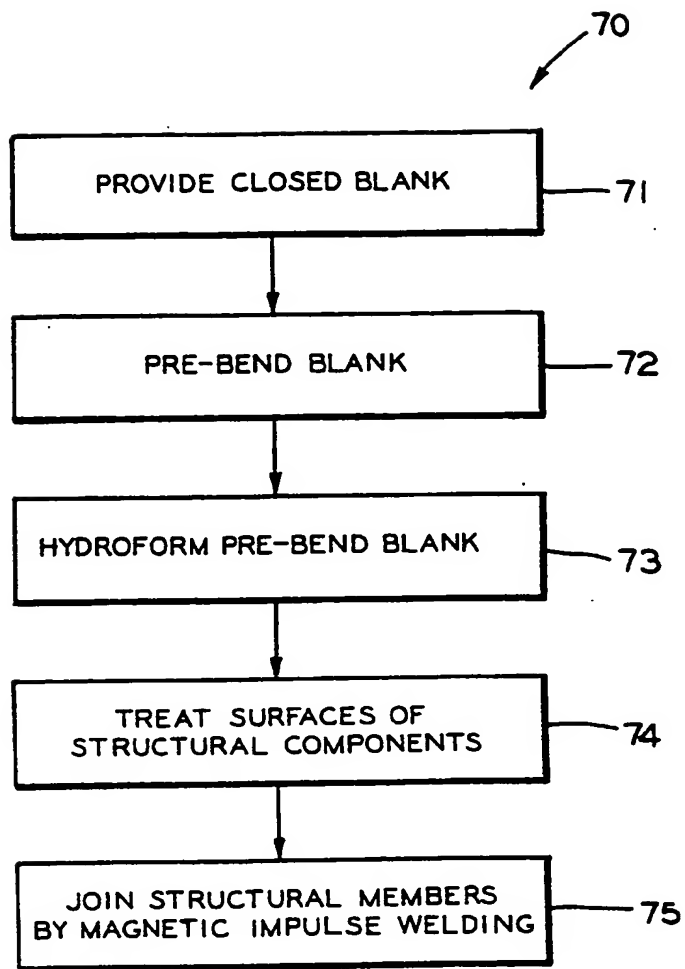
**FIG. 16**



**FIG. 17**

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**FIG. 18**

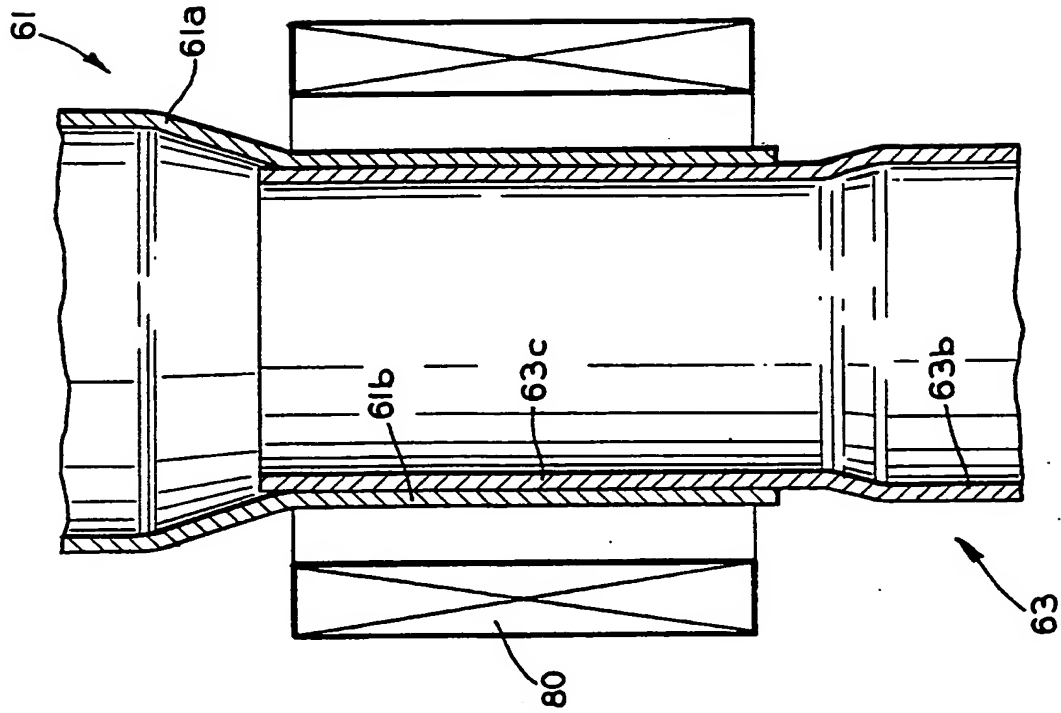


FIG. 20

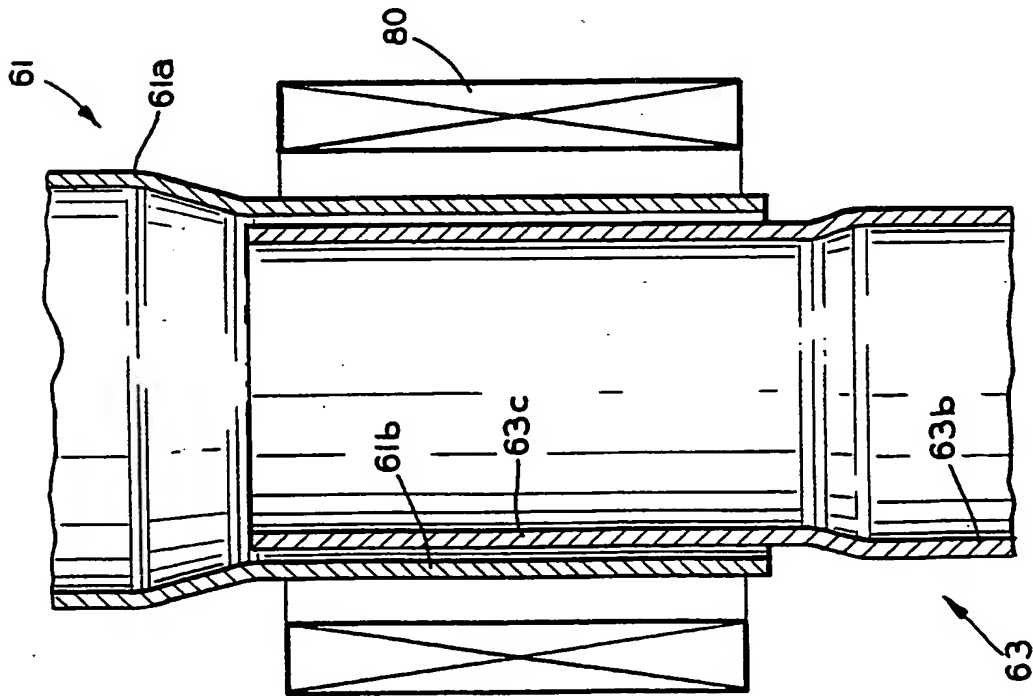
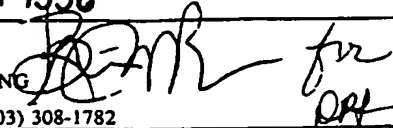


FIG. 19

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US96/10371

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> IPC(6) : H05B 6/10; B23K 13/01 US CL : 219/603, 617; 228/107; 72/56 According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B. FIELDS SEARCHED</b> Minimum documentation searched (classification system followed by classification symbols) U.S. : 219/603, 617, 633, 635; 228/107; 72/56. Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 3,603,759 (PEACOCK) 07 SEPTEMBER 1971 SEE THE FIGURE AND COL. 1, LINES 6-26.	1-17
Y	US, A, 3,258,573 (MORIN ET AL) 28 JUNE 1966 SEE THE ENTIRE DOCUMENT	1-17
Y	US, A, 5,326,957 (KARUBE ET AL) 05 JULY 1994 SEE COL. 1, LINES 13-19.	1-17
Y	US, A, 4,922,075 (SOFUE ET AL) 01 MAY 1990 SEE COL. 1, LINE 11 - COL. 3, LINE 15.	1-17
Y	US, A, 5,339,667 (SHAH ET AL) 23 AUGUST 1994 SEE COL. 1, LINE 5 - COL. 2, LINE 2.	12-15
Y	US, A, 5,170,557 (RIGSBY) 15 DECEMBER 1992 SEE THE ENTIRE DOCUMENT.	12-15
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 23 AUGUST 1996		Date of mailing of the international search report 15 OCT 1996
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230		Authorized officer PHILIP H. LEUNG  Telephone No. (703) 308-1782

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US96/10371

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US. A. 3,603,760 (CHELJUSKINTSEV ET AL) 07 SEPTEMBER 1971. SEE THE ENTIRE DOCUMENT.	1-17
A	US. A. 4,513,188 (KATZENSTEIN) 23 APRIL 1985 SEE THE ENTIRE DOCUMENT.	1-17
A	US. A. 5,157,969 (ROPER) 27 OCTOBER 1992 SEE COL. 1, LINE 5 - COL. 3, LINE 12.	12-15